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MACKENZIE DELTA GAS DEVELOPMENT SYSTEM



VOLUME 1

PROJECT DESCRIPTION



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October 1974

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I. DEVELOPMENT OVERVIEW

Gas production from the Mackenzie Delta and Beaufort Sea areas of northern Canada would be expected to start in 1979. The following project description outlines the techniques and facilities necessary to produce the gas and condition it for transmission to southern markets.

In each field, producing gas wells would be directionally drilled from a gravel-covered pad or cluster. A field might have from one to four clusters. The wells within a cluster would be in rows, and spaced far enough apart for efficient, safe development and production.

The gas produced from each well would be gathered by individual lines to a central point at or near the cluster for initial conditioning. Current studies indicate conditioning would consist of flow measurement and hydrate control. Test separation facilities would be provided for measuring individual well performance. It appears that hydrate formation could best be controlled by means of indirect heat or electrical heat-tracing. Methanol would also be used to complement heat during start-up.

The heated gas would be moved through pipelines to processing plants where it would be treated to transmission-line specifications. Treatment would include separation, dry-desiccant dehydration, and hydrocarbon dew-point control by refrigeration.

II. FACILITIES

A. WELL-CLUSTER SYSTEMS

1. Cluster Facilities

Figure 1 provides a plan view of a typical cluster of producing wells. The size of each cluster pad is primarily a function of the number of wells to be drilled at each site. It is anticipated that a maximum spacing of 180 feet between wells would provide room for both drilling and workover rigs, and ensure safe and efficient operation of the wells. In some cases, where the producing zones are relatively shallow, several smaller clusters might be used for satisfactory drainage of the reservoir.

The cluster layout provides adequate separation of various potential sources of hazards. The minimum distances between wells, process modules, heater module, emergency living quarters, etc., would satisfy the safe working regulations of any applicable codes.

Wells and facilities at each cluster would be founded on a gravel pad thick enough to preserve the underlying permafrost. It is anticipated that the gravel would need to be about 4-6 feet deep. Buildings and other heat-generating equipment would be on piles, above a gravel pad. In some areas, the height of the entire pad and perimeter dyke would be dictated by local conditions such as storm surge or flood height.

The perimeter dyke would contain any minor spill that might occur at the cluster. In addition, the surface grading would ensure that run-off water was channeled to a holding pond for subsequent disposal.

The gas would be transmitted by gathering lines to central processing plants at Taglu and Parsons Lake (Fig. 2). The lines would

be insulated and supported above ground on piles, to prevent thermal disturbance in the permafrost from the warm gas. Minor rivers and channels would be crossed by above-ground support systems; major rivers by underground lines.

Permanent facilities at each cluster would include the following equipment:

a) Wellheads

Each wellhead would be equipped with automatically controlled surface and subsurface safety valves, designed to close in the well in the event of any equipment malfunction downstream or downhole.

b) Flowlines

Lines, rated to withstand maximum operating pressure, would link wellheads to a valve manifold in the process module.

c) Process and Utility Modules

These modules would contain flow-control valves, inlet valve manifold, test separators for measuring gas and liquids, metering equipment, heat exchangers, instrument air-compressors and methanol-injection pumps (wellhead and gathering system). All process equipment would be provided with safety relief valves, vented to a common flare stack located a safe distance from wells and facilities.

d) Control-Room Module

This module would contain process-control equipment, communications systems, electrical-generation equipment, and emergency living quarters.

e) Helicopter Pad

f) Tank Farm

The tank farm would provide storage for methanol, diesel fuel, propane refrigerant and brine, where necessary.

g) Refrigeration System

It is anticipated that refrigeration systems would be required only in isolated cases. They would be used to refrigerate the top portion of the casing string and maintain the permafrost in its frozen state.

h) Compression Facilities

Some clusters might require compression facilities, either initially or at some future time, to boost the pressure of the well fluids for gathering-system transmission.

2. Cluster Activities

The development schedule shown in Figure 3 provides the start-up dates and probable duration of cluster and gathering-system activities that would precede the start of gas production from the Mackenzie Delta. The schedule assumes that production would begin during the second or third quarter of 1979, but could readily be altered to suit any later start-up date. It presents a current best estimate of the time spans and would be revised as necessary.

a) Normal Operation

The raw gas produced from the wellhead would be metered, then diverted to the central processing plant. Because it contains condensable water, it would be heated or dehydrated at the cluster to prevent hydrate formation. Cluster operations would be remotely monitored and fully controlled from the central processing plant.

Crews would not normally be housed at the cluster during operations, but permanent accommodations would be provided for use in emergencies or bad weather. Chemicals stored at the cluster might include about 500 barrels of diesel fuel, several hundred gallons of lubricating

and hydraulic oil, 1,000 barrels of propane refrigerant, 500 to 1,000 barrels of methanol, and 200 barrels of heat-transfer fluid (brine).

b) Workovers and Infill Drilling

In general, little rig activity would be expected for the first four to six years after the initial drilling and completion program. After that some remedial well work and infill drilling would probably be necessary. The remedial workovers would be similar to the completion operations (i.e., same type of movement, manpower requirements and activities). Workover frequency could be roughly estimated at one to two workovers per year per six to eight well clusters with each job lasting 15 to 45 days. Additional infill drilling would probably add one well per year per cluster, with rig activity going to about the tenth year of operation.

B. FIELD GATHERING SYSTEM

1. Design

Figure 2 shows the general routes within which gas-gathering systems would be located. Choice of specific routes would be based on detailed field surveys. Routes would be chosen to minimize the number of water crossings, and to avoid ice-rich soils, steep slopes and other areas sensitive to thermal disturbance or water erosion.

Gas-gathering lines would generally be constructed above ground, on supports founded on piles frozen into the permafrost. Expansion loops would provide the necessary freedom of movement to prevent excessive stress build-up during extreme temperature conditions. The supports would be close enough together to prevent excessive vibrations during high winds, and designed to allow limited movement of the pipe. Gathering lines would be underground only at major water crossings, where the absence of permafrost makes burial safe. The depth of burial would be governed by possible scour depths. Lines would be suspended above the surface at minor water crossings, with adequate clearance if the water-course were navigable.

Elevated lines would be high enough to clear maximum storm surges, floodwater crests, and maximum snow depths. Minimum clearance under the pipe would be four feet, to allow passage for small animals. Underpasses (or overpasses) at intervals would provide crossings for larger animals and vehicles. Lines would be coated externally with an anti-corrosive paint system, then insulated to minimize heat losses. Gathering-system working pressures would vary, with a maximum in the order of 2,600 psig. All pipe and fittings would conform to a low-temperature specification, to minimize the risk of brittle fractures at the low ambient service temperatures.

Some portions of the gathering system might need compression facilities to start with, in order to deliver gas to the central plants at the required inlet pressures. Additional gas compression would be needed for the system as subsurface reservoir pressures declined. This additional compression might conceivably be installed at wellhead clusters, gas plants, or key gathering-system junctions. Additions would be modular and installed in the same way as described for cluster and gas-plant modules.

2. Normal Operating Activities

Inspection, maintenance and repairs to gathering-system equipment would be carried out regularly by maintenance personnel from the central plant. The inspection would be by regular aerial reconnaissance, supplemented by a ground-level visual check each spring and fall. It would include: measurement of any pile or pipe settlement, corrosion-coupon checks, cathodic-protection surveys, inspection of external coating and metal sheathing, and pipeline-valve inspection and actuation.

C. PROCESSING PLANT

Two gas-processing plants would be built in the general Mackenzie Delta study region. One would be at Taglu, and would process a total of 1.0 BCF per day from the Taglu and Niglintgak fields; the other would be at Parsons Lake, and would process 0.5 BCF per day.

1. Plant Facilities

Each plant would include a fully integrated processing unit with associated communication system, management offices, personnel accommodation, utility and maintenance facilities, water-treatment and waste-disposal units, airstrips, helicopter pads and river docks. The Parsons Lake plant would have an all-weather airstrip suitable for jet aircraft.

The general layout for both plant and main process buildings would be governed by climate and geography. All equipment would be housed, and the various essential buildings might be serviced by utilidors, including a corridor so that operators would not have to go outside too often in the course of their normal work. (Air coolers would be an exception.) All process buildings would be of modular construction, with modules being completed as far as possible at a southern assembly yard to keep on-site labour to a minimum. Layout of the general site would allow for the effects of prevailing winds and snow drifting. The Taglu plant would be on low delta land where the high-water flood mark would determine the height of the dykes, their outside surface finish, and the amount of landfill required. The Parsons Lake plant would be above flood level, but would still need fill material for permafrost insulation.

2. Process Design

Raw gas from the wells would have to be processed for transport to southern markets, since essentially all condensable water and hydrocarbon must be removed to meet transmission-line specifications. Mackenzie Delta gas contains no sulphur products and therefore would not need to be treated for sulphur removal.

At the Taglu plant the raw gas would undergo initial gas/liquid separation, after which it would be dehydrated and then refrigerated to remove the liquefiable hydrocarbons. The residue gas would then be delivered to the main gas-transmission system.

At the Parsons Lake plant, after initial gas/liquid separation, the gas would be refrigerated to condense undesirable water and hydrocarbons. The residue gas would then be compressed, cooled, and delivered to the main gas-transmission system.

3. Normal Operation

Operation of well clusters, gathering systems, processing plants and support systems would be controlled from a computerized operations control centre at each processing plant. A highly sophisticated computer production-control system would be used. It would record and identify abnormal conditions and, where practical, initiate corrective action automatically. Equipment would be maintained by personnel from the central plant.

Each plant would be completely self-supporting so far as qualified operations and maintenance personnel are concerned. Maintenance shops would service the plants, gathering systems, well clusters and support facilities. Shops would be equipped to meet the day-to-day requirements

of the mechanics and the electric and instrument repair personnel, as well as for major mechanical repairs by personnel specially brought in.

III. ACTIVITIES AND ACCOMMODATIONS

A. TRANSIENT ACTIVITIES

1. Pre-Construction Activities

These activities would include route surveys (from aircraft and overland), soil sampling and shallow coring along alternative gathering-system routes. They would generally be carried out in winter by small crews commuting to the work site daily from a central camp. Equipment and men would travel on prepared snow roads constructed along the routes. Noise levels would be low and activities at any specific location would not last longer than from one to two weeks. Possible pollutants would be mainly diesel fuel and lubricating oil.

2. Construction Activities

a) Clusters

Gravel-pad construction at the clusters would involve moving and placing large amounts of gravel (estimated at 250,000 cubic yards maximum per eight-well cluster location). Open sumps suitable for containment of drilling fluids and sewage would be constructed in preparation for the arrival of drilling rigs. The work would be carried out chiefly in winter. It is anticipated that gravel would be transported to the site over snow roads directly from the pits; however, in some areas it might be barged during open-water months and stockpiled until freeze-up. Heavy construction equipment would be used, and crews would be housed in temporary portable camps at each cluster location.

On-site construction of permanent facilities would consist mainly of installing, interfacing, testing and commissioning prefabricated modules, each weighing several hundred tons. Transportation and installation

methods at the cluster sites would be the same as for the gas-plant modules. Activities during this period also include installing the pipe work and instrumentation systems linking wellheads to processing-facility modules, and these modules to the gas-gathering system.

Heavy construction equipment used on various aspects of the job would operate within the confines of the gravel pad after the modules had been placed. Crew size at peak construction would approach 40 men. Noise levels would be the same as for exploratory drilling. Possible pollutants stored at the cluster site would include diesel fuel, lubricating oil and anti-freeze glycols.

b) Plant Sites

Construction activities at the plant sites would start during the winter of 1976-77 with gravel hauling and site preparation (Fig. 3). Gravel pads would be constructed at plant sites and staging area. Dock facilities suitable for handling plant modules would be built between staging areas and plant sites. This work would be carried out over two years, so that by early 1978 piling might be set for placement of the plant modules, which would be barged to the staging areas that summer. Module placement and interfacing would be carried out during the winter of 1978-79, and the plant would be ready for commissioning and start-up by mid-1979.

c) Gathering System

Construction of the pipeline systems linking well-cluster facilities to gas-processing plants would be carried out in winter, except for certain activities at cluster or plant sites where work would be confined to gravel pads. Crews would be accommodated at central base camps and transported daily to and from the construction site. Activities

along the right-of-way would consist primarily of the following phases:

- i) Preparing the right-of-way (minor bushing in some areas and some hillside modification).
- ii) Constructing pile supports, suspension systems for above-ground water crossings, and trenches for buried water crossings.
- iii) Positioning, welding, coating and insulating the pipe (including burial of underground sections).
- iv) Pressure-testing completed installation.

Heavy equipment would be required in all phases. Pile foundations would be sunk at least a month before pipe-laying, to be sure the piles were properly frozen in before being loaded. Pipe assembly facilities would be set up at the central base camps, and as much prefabrication as possible would be carried out before transporting pipe sections to the installation site. Construction spreads for the gathering system would involve 75 to 125 men.

Gas-compression facilities would be modularized as far as possible and transported, installed and interfaced in the same manner as the gas-plant modules.

3. Development Drilling and Well Completion

Development drilling would include the actual drilling operation and rig relocation. The rig would be moved as close to the cluster as possible by barge, then hauled in by truck or tracked vehicle over snow or gravel roads. For on-site rig movement, skidding procedures would be used the year round.

The 35 to 40 people engaged in the drilling operation and associated activities would be housed on site in temporary camps. The

drilling would generate materials such as diesel oil, oily wastes, spent-acid water, drilling mud, and cuttings. All drilling wastes would be disposed of in the sump where any hydrocarbons would be skimmed and incinerated. Sump contents would be allowed to freeze, and the sump would be backfilled and become part of the pad structure.

Completion activities might be carried out by a drilling rig or another smaller rig. Completion would generally take 15 to 20 days per hole and would need 5 to 10 men. Processes would include displacement of the well. Both mud and acid waste would be disposed of in the sump. Production testing would produce effluents such as spent-acid and formation water, and liquid and gaseous hydrocarbons. Hydrocarbons would be fully combusted before emission.

B. PERSONNEL ACCOMMODATION AND SUPPORT FACILITIES

Accommodation facilities for the Mackenzie Delta Project would be designed to meet the needs of both construction and operating personnel. The designs would also include facilities for sewage and waste disposal, and recreational facilities.

1. Investigation and Survey

As the crews would be small and would be in the field early, they would use the accommodation and support facilities the producers had already provided in the area.

2. Construction

Some construction crews, such as those for gravel and piling, would use temporary facilities near the project area. The main accommodation for plant personnel would be installed in time for the main construction crews.

3. Drilling and Well Completion

Drilling rigs would have personnel accommodations to suit their type of operation.

4. Operating Phase

Coordination of gas production in the Mackenzie Delta would be centralized at the gas-processing plants. Complete living quarters for all operations personnel, including recreation and support facilities, would be placed near the central plants.

Solid refuse from all operations would be incinerated with the residue from sewage treatment; and the ash and remaining noncombustible solids would be buried in an approved landfill.

All remote sites where work would be going on regularly would have shelters equipped for emergencies.

The transportation requirements for moving materials and equipment to the field sites will be determined by the nature of the work and the availability of local resources.

A number of factors will be considered in the selection of sites for the study. The availability of local resources, the nature of the work, and the availability of local resources will be considered in the selection of sites for the study. The availability of local resources, the nature of the work, and the availability of local resources will be considered in the selection of sites for the study.

The staff will be selected by the local community for the study and will be responsible for the collection and analysis of the data. The staff will be selected by the local community for the study and will be responsible for the collection and analysis of the data.

During the study, the staff will be responsible for the collection and analysis of the data. The staff will be selected by the local community for the study and will be responsible for the collection and analysis of the data.

	Estimated population	Estimated population	Estimated population
Area	100	100	100
Area	100	100	100
Area	100	100	100
Area	100	100	100
Area	100	100	100
Area	100	100	100
Area	100	100	100
Area	100	100	100

The staff will be responsible for the collection and analysis of the data. The staff will be selected by the local community for the study and will be responsible for the collection and analysis of the data.

C. TRANSPORTATION

1. Logistics

The transportation requirements to develop, construct and operate the gas producing and processing systems would embrace all conventional modes of arctic travel.

A transportation plan would be worked out for each individual site and activity. Year-round access would be provided at all permanent sites in the form of helicopter pads with fuel supplies. Each gas plant would be serviced by a permanent airstrip, and the one at Parsons Lake would also be able to handle jets. Air traffic would probably peak during the construction period.

Air traffic to be handled by the Inuvik airport for the drilling and production phase of the project would run throughout the year at approximately the present peak seasonal load.

During 1979, the final year of construction for the two gas plants, the increase in air traffic at Inuvik would be as follows:

	<u>Twin Otter Landings</u> (Leased Aircraft)	<u>Passenger Arrivals</u> (Commercial)	<u>Passenger Departures</u> (Commercial)
June	41	190	38
July	79	380	228
August	131	494	418
September	138	494	494
October	138	456	494
November	90	228	418
December	39	38	190

Anticipated barging requirements via Hay River for material, fuel, equipment, and drilling supplies for the project are outlined as follows:

1975	-	82,000 tons
1976	-	95,000 tons
1977	-	97,000 tons
1978	-	113,000 tons

In addition, 15,500 tons of gas-processing modules along with 10,000 tons of pipe would be shipped in 1978 from Vancouver via the Bering Strait.

After completion of the project, the on-going drilling expected to result from the development would need about 100,000 tons of annual barge services.

2. Investigation and Survey

Field teams would be transported in summer by helicopter and in winter on wheeled or tracked vehicles. Plant and cluster sites would be drilled for core samples in winter surveys.

River crossings and dock sites would be investigated by boat in summer and by truck over the ice in winter. Supplies for surveys would be transported by aircraft.

3. Drilling and Well Completion

Drilling rigs would be barged to staging sites, then moved over-land by truck or tracked vehicle on snow or gravel roads. For on-site movement of rigs, conventional skidding techniques would be used.

4. Construction Phase

Much of the transportation early in the construction phase would involve hauling gravel for pads at the cluster, plant and staging sites, airstrips, etc. Tandem trucks would move about three million cubic yards of gravel from the pits near Ya Ya Lake and Parsons Lake. Gravel-hauling would

need a crew of about 150 with 40 to 50 support personnel; they would be accommodated in portable camps at the gravel sites. Some gravel also might be barged in summer and stockpiled at the staging sites for winter transport.

Piles for plant construction would be barged to plant sites in summer. Piling for pipeline support would be barged to areas close to right-of-way and stockpiled for winter installation.

Permanent docks would be built in summer at the plant-site staging areas. The dock area would accommodate plant module off-loading. Steel sheet piling for the docks would be barged from Hay River.

The summer before start-up, the larger gas-plant modules and equipment would be barged from Vancouver to the plant sites. Small components for plants and clusters would be barged down the Mackenzie River from the railroad. Off-loading and transport of modules would be by self-powered transporters. Site preparation at the plant area, the staging area, and between staging area and the plant would be carried out before arrival of the modules, to provide an all-weather surface to carry the module loads.

Pipeline materials would be off-loaded at three sites, Kumak Channel, Taglu site and the end of Eskimo Lakes. Pipe would probably be hauled by barge down the Mackenzie River system, but the sea route from the Pacific is also a possibility. Pipe would be moved to line locations and installed during winter.

Each main accommodation complex would be barged to the site and installed in the summer of 1977. Fuel, supplies and equipment would also be transported to the site at that time.

5. Normal Operation

Once gas production was underway, transportation would become routine, encompassing the following activities:

- a) Re-supply of materials by barge to staging areas and plants.
- b) Inspection trips to clusters.
- c) Personnel changes.
- d) Surveillance of pipelines.

D. MANPOWER

During the investigation and survey phase, small investigative teams would spend short periods in the field to delineate working conditions, locate sites for plants and docks, describe topography, check routes for pipelines, and locate roads, clusters, gravel deposits and airstrip sites.

Manpower requirements during construction of the clusters, gathering system and plant would vary greatly with time of year and activity. A maximum force of 250 workers per site would be anticipated.

Drilling operations would require 35 to 40 workers in all, and completion activities would normally employ 5 to 10 men. With support services for these operations employing another 5 to 10 persons, simultaneous drilling and completion activities would need a total work force of 40 to 50 people per cluster.

Operating-personnel requirements for a typical Mackenzie Delta plant of 0.5 to 1.0 BCFD would be about 25 to 35 men.

This estimate includes producer employees and contract employees for normal operations only. Expansion or major overhaul of facilities would entail additional staff.

E. CONTINGENCY PLANS

1. Drilling and Completion

Contingency plans would be designed to suit individual sites and operations phases. Sophisticated equipment, preventive techniques and trained competent crews will minimize the risk of spills or blowouts. Should such occur, the site design would provide for 100 per cent containment of fluids, and crews would be able to control effluents immediately.

2. Gathering System and Plant

The central plant control room would be the focus for detection of an upset in operating conditions. Any abnormal pressure, temperature or flow condition, or fire, would automatically initiate appropriate corrective action or shut-in. Any leak or failure of a pipeline would require on-site manual inspection before facilities were returned to operation. Extensive precautions would be taken to prevent gathering-system leaks or failures.

Accidental spills of hydrocarbons or petroleum products at the plants or well clusters would be contained by the diking system. Booms and skimming devices would be available in the dock areas to contain and clean up any petroleum products.

At the cluster, all principal buildings would be equipped with automatic fire extinguishing systems. The plants would be designed with a shut-down system that would eliminate the fuel source for any fire by depressuring the affected area to the flare system. Gas-detector systems would be installed in all critical areas.

All key control areas, such as the control room, electrical motor-control centre, and power house, would be equipped with extinguisher systems.

Hand and portable fire-extinguishers would be appropriately located throughout each building.

The living complex would have a water fire-fighting system (not required for the other plant areas).

IV. CONTROL

A. WASTES AND EFFLUENTS

Waste and effluent treatment and disposal are important aspects of all arctic operations. The processes of Mackenzie Delta gas development would be designed to minimize or eliminate detrimental effects from any operation, including waste and effluent.

1. Drilling and Completion

Specially developed mechanical sumps and mud-handling systems would facilitate disposal of drilling muds and wastes. The mud sumps would be able to handle 10,000 barrels per well of waste, including drilling mud, cuttings, excess fines, diesel oil, oily wastes and spent-acid water. Hydrocarbons would be skimmed and incinerated, solids would settle in the sumps, drilling-mud would be re-used and liquids reclaimed where possible. Special additives such as diesel oil, lubricants, soda ash or sawdust that might be needed to alleviate drilling problems would also be handled by the sump.

2. Normal Operation

The processing plants would be designed to meet high standards for wastes and effluents. Deleterious effluents would be minimized by preventing the emission of hydrocarbons, using air-cooling throughout, injecting the relatively small amount of plant process water, treating all sewage wastes in a comprehensive secondary-treatment system, incinerating solid wastes, and burying nonreducible remains.

a) Water

Water recovered from the gas in the dehydration process would be injected into a suitable disposal well. No water would be used for cooling or steam.

Liquid and solid wastes from the washrooms, laundries or kitchens of the living complex would be treated to produce an effluent acceptable to government standards.

b) Air

Cooling plant-process streams with ambient air would produce a hot-air effluent. The air leaving the coolers would be as warm as 130°F, and would contain no substances not in the air before it was drawn through the coolers.

Gas combustion by-products from the two plants would be discharged to the atmosphere.

From time to time gaseous hydrocarbons would have to be flared to prevent overpressuring a piece of equipment, or during plant start-up operations. Such emergency flaring would be carried out in a tall stack, so that the release of combustion by-products would not affect surface ground conditions. The system would be designed to avoid flaring liquid hydrocarbons. If for any reason the liquid-hydrocarbon disposal system were inoperative, the plants would be shut down once surface storage had been filled. Similarly, waste water would not be discharged to open storage pits.

c) Noise

Individual plant equipment would meet a noise-emission standard of 85 dBA at a distance of three feet for the working levels, if necessary by provision of a sound-resistant wall around the equipment. Should the operator have to go inside the sound-resistant wall, he would be required to wear ear protection.

Mackenzie Delta gas plants would be designed to meet a noise

level of 65 dBA at the plant lease boundary, which is assumed 500 feet outside the plant dyke. Living quarters for plant personnel would meet a noise level of 50 dBA.

d) Monitoring Techniques

Emissions from the gas plants would be monitored continuously. Weather stations would be installed to provide continuous readings of wind velocity and direction, humidity, snowfall, rainfall and temperature.

Samples of effluent water would be taken once a day from the sewage-treatment plant or as required by the environmental authorities. Laboratory checks would ensure that it met environmental standards.

Gas-detection monitors would be installed in all hazardous locations to block in and depressure the gas plants in case of a leak.

B. SITE RESTORATION

1. After Construction Activities

Should activities at well clusters, gathering systems, gravel-source areas, dock facilities, process plants and base-camp facilities have resulted in any damage to the tundra, the affected areas would be restored with insulation followed, if necessary, by replanting.

Any disturbance at stream and river crossings would be repaired to prevent bank erosion and gouging. All well-cluster, gathering-system, base-camp and support facilities would be closely monitored by visual and photographic inspection and any damage noted would be remedied as soon as possible.

2. On Terminating the Operation

The following points summarize the extent of terrain restoration procedures that would be carried out at the end of the useful life of a well cluster, gathering line, or plant facility:

a) All wells would be plugged and abandoned in accordance with existing regulations. Tubular goods would be cut off below ground level and capped.

b) Much of the gravel would be salvaged and transported to other construction locations. Any not required would be left in place.

c) All elevated pipelines or electrical transmission lines would be removed. Pile supports would be cut off at ground level and right-of-way restored as nearly as possible to its natural state.

d) Buried pipelines or electrical transmission lines would be removed, or, alternatively, abandoned in place with approval of the regulatory bodies. Rights-of-way would be restored to their natural state.

e) Processing-plant and cluster equipment would be salvaged wherever feasible. Some large equipment would be retired in place inside a locked fence.

V. POSSIBLE ALTERNATIVES

The gas-production and gathering system descriptions provided here have been based on technical studies completed up to the time of this report. These studies were built on a particular set of assumptions, which are not necessarily valid throughout the geographic area of interest. Nor do the basic assumptions and conclusions necessarily represent an optimum for the specific cases so far considered.

All pre-development planning to date is in fact based on a "recycle" strategy whereby early study results are continually reprocessed, revised and adjusted as new information and additional alternatives are recognized.

Some likely eventualities and alternative possibilities, some of which are now under review, are as follows:

a) Additional gas reserves would very likely be delineated at various locations in and around the immediate area of interest. These discoveries could then result in new gathering systems, additional plants and support facilities. The facilities described are expected to be capable of handling all gas production within a 25-mile radius of each plant. Other gas discoveries might require additional facilities similar to those described. Any oil discoveries in the area would also require new facilities.

b) Producing conditions such as flow-stream pressure, temperature and composition would differ from area to area. Although hydrogen sulphide has not yet been detected, future gas discoveries might contain enough to require alternative processing techniques.

c) Reheat stations might be needed to maintain gas temperatures throughout the lengthy gathering systems. Other provisions that could be included in these stations are alcohol injections and depressuring devices.

d) Hovercraft might be introduced where they could be proved to offer a significant economic or logistic advantage over other available forms of transportation.

FIGURE 1

CONCEPTUAL LAYOUT — WELL CLUSTER
PRODUCTION FACILITIES

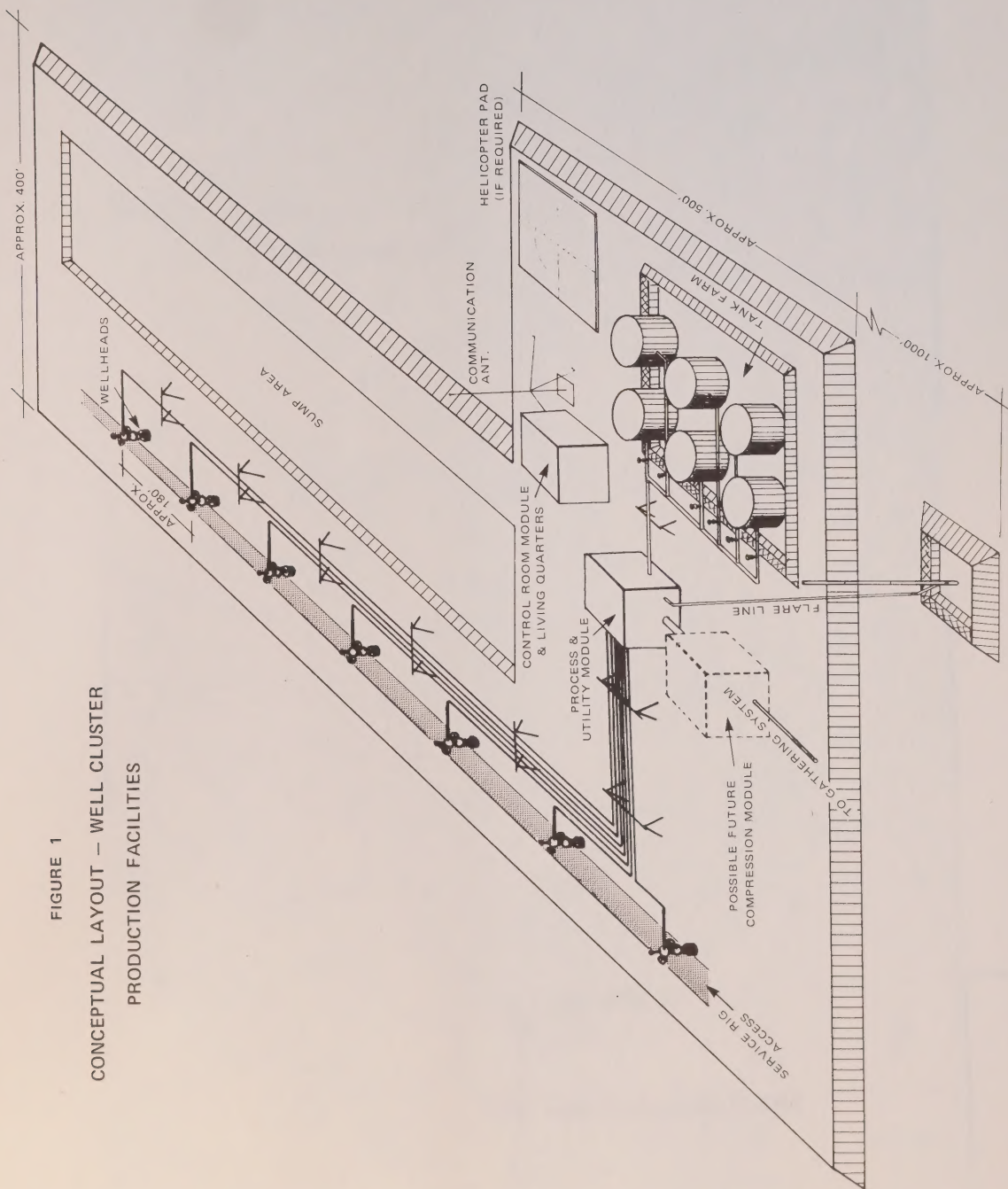


FIGURE 2

FACILITY LOCATIONS



FIGURE 3
CONSTRUCTION ACTIVITIES

